# OUTLINE OF RESEARCH WORK FOR THE DEVELOPMENT AND ASSESMENT OF INNOVATIVE IGU DESIGNS (WITH IMPROVED THERMAL INDICES)

## BACKGROUND

Presently, it is very common to have insulated glazing unit (IGU), which incorporates plastic layers, which are planar-parallel to glass layers. Thermal indices of these IG units (thermal transmittance or U-value, solar heat gain coefficient or SHGC, visible transmittance) are adequately predicted and calculated by fenestration thermal performance programs like THERM5 and WINDOW5. These programs allow us to find optimal and the most effective combination of gap thickness, gas filling, and surface low-e coating. However, these IGUs may demonstrate significant decrease in surface temperatures near the bottom part of IGU that creates uncomfortable conditions in a room and reduces durability of a fenestration system (e.g., condensation occurrence that obscures vision, mold, etc.). Using non-parallel layers between two glass layers can be demonstrated to correct this effect and to produce improved distribution of surface temperatures. In order to asses the performance of these new IGU systems, it is no longer feasible to use existing fen4stration tools, but it is necessary to use more detailed computational fluid dynamics and heat transfer models.

## OBJECTIVES

The primary objective of this project is to develop new IGU designs that would maintain desirable optical properties (i.e., visible transmittance, clarity, and SHGC) while improving thermal performance and especially improving temperature filed on warm side of the IGU. These improvements are based on using nontraditional elements in glazing as inserts, curved or hanged films and blind inside glazing cavity. It is expected that new designs would have higher inside glazing surface temperature and condensation resistance index than currently available, with only slight changes in technological process of IGU manufacturing.

Secondary objective of this project is to develop improved tools for predicting thermal and optical performance of non-traditional systems like this one. In the process of the development of such the and can be estimated and compared by numerical simulations using fluid dynamic software.

## SCOPE

Develop the glazing unit design with improved thermal indices based on existing knowledge of the capabilities of computer 2-dim and 3-dim modeling using CFD software [1,2]. Some of obtained preliminary results and schematic presentation of research directions according to the subject of this project are given in Annex.
The following basic stages of the research work is supposed to accomplish:

- Numerical modeling and choice designs with optimal sizes and characteristics
- Making experimental/pilot IG unit samples
- Performing physical testing of experimental samples.

DELIVERABLES

Final report including simulation and testing results and description of developed IG units shall be produced at the end of the project. Also intermediate reports shall be produced at the end of each stages of the project.

ESTIMATED COST

$150 (200)

ESTIMATED DURATION

Final results and report shall be produced 18 (24) months from the start of the project.

## REFERENCES

1. FDI 2000. "Gambit 1.3.2  Users and Reference Manual". Fluid Dynamics International, Fluid Dynamics Analysis Package Revision 1.3.2, Evanston, IL.
2. FDI 2001. FLUENT 6.0. Users and Reference Manual. Fluid Dynamics International, Fluid Dynamics Analysis Package. Fluent Inc. November 2001.

Annex

# Descriptions and preliminary results of heat transfer modeling of various solutions of IG units designs with improved thermal properties

## 1. Two layer IG unit with insert plastic film

As a basis IG unit for comparison thermal properties we take air filled glazing system with gap width W = 16.5 mm and height H = 1.2 m and glass width 4.7 mm (inside glass with ε = 0.16).
Geometry and the boundary conditions accepted in numerical modeling are shown in Figure 1.

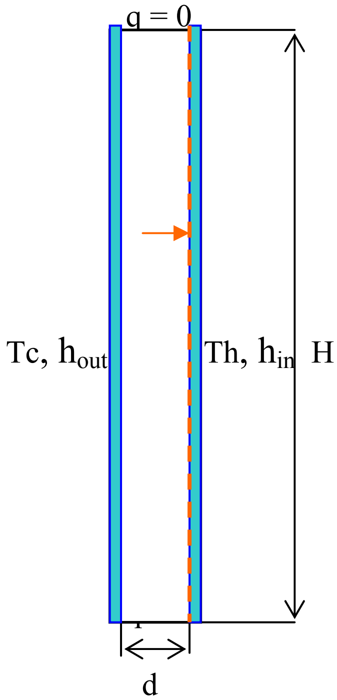



Figure 1. Designations and boundary conditions of the model of double IG unit.

We defined film coefficient $h_{out}$ = 29 W/(m$^2$°C) and $h_{in}$ = 7.7 W/(m$^2$°C), temperature Tc = -17.8 °C and Th = 21.1 °C.
The scheme of basis IG unit with plastic translucent inserts (height 25 mm) in the bottom and top parts is shown in Figure 2.

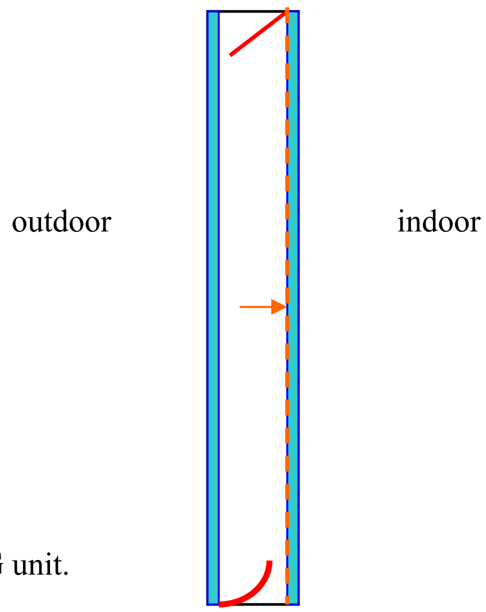



Figure 2. Inserts in the gap of IG unit.

Temperature distribution in the bottom and top parts of IG unit with inserts is shown in Figure 3.

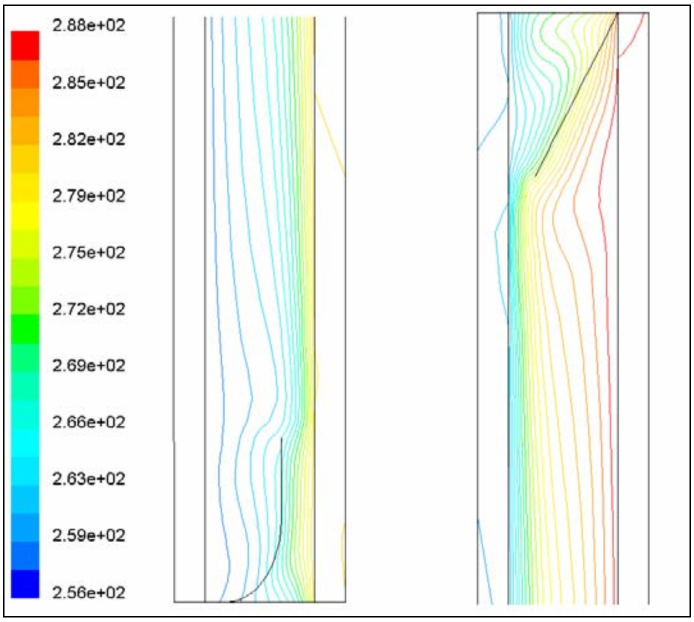



Figure 3. Calculated temperature field of IG unit with inserts. Fluent 6.0.

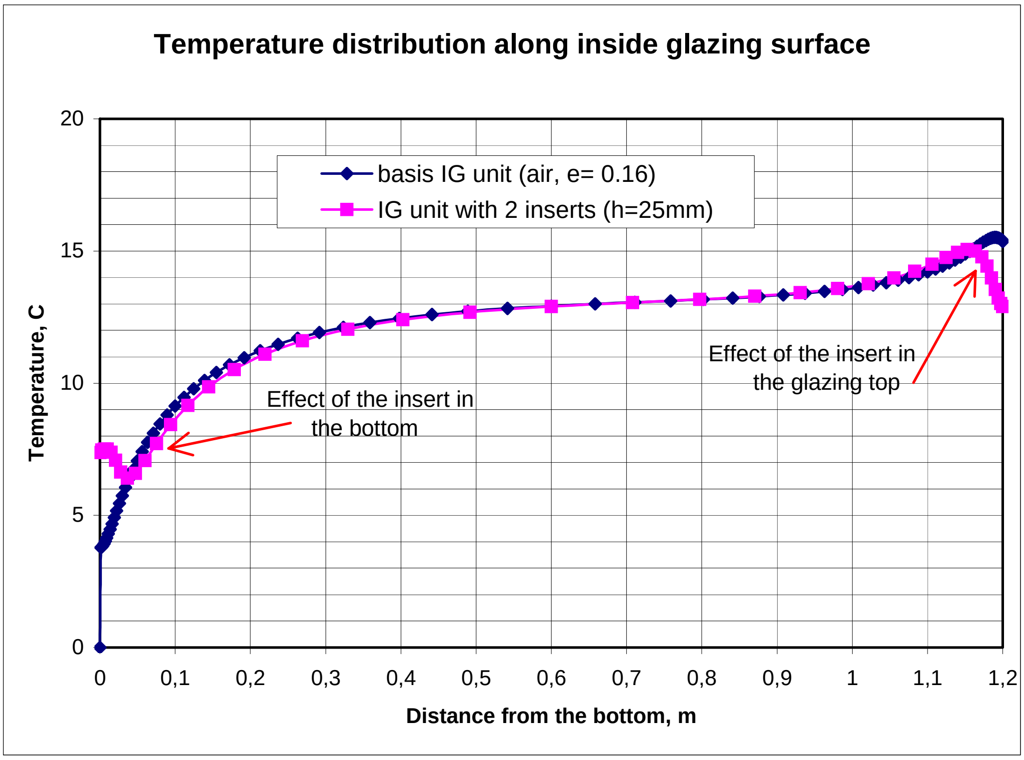



Figure 4. Comparison temperature distributions along inside glazing surface.

Temperature distributions along inside glazing surface for basis IG unit and IG unit with inserts are shown in Figure 4.
The insert in the glazing bottom increased temperature in bottom part on 4°C. Size of insert effect can be estimated approximately by expression $h * 1.6$, where $h$ is insert height.
Results of numerical modeling are summarized in the Table 1.

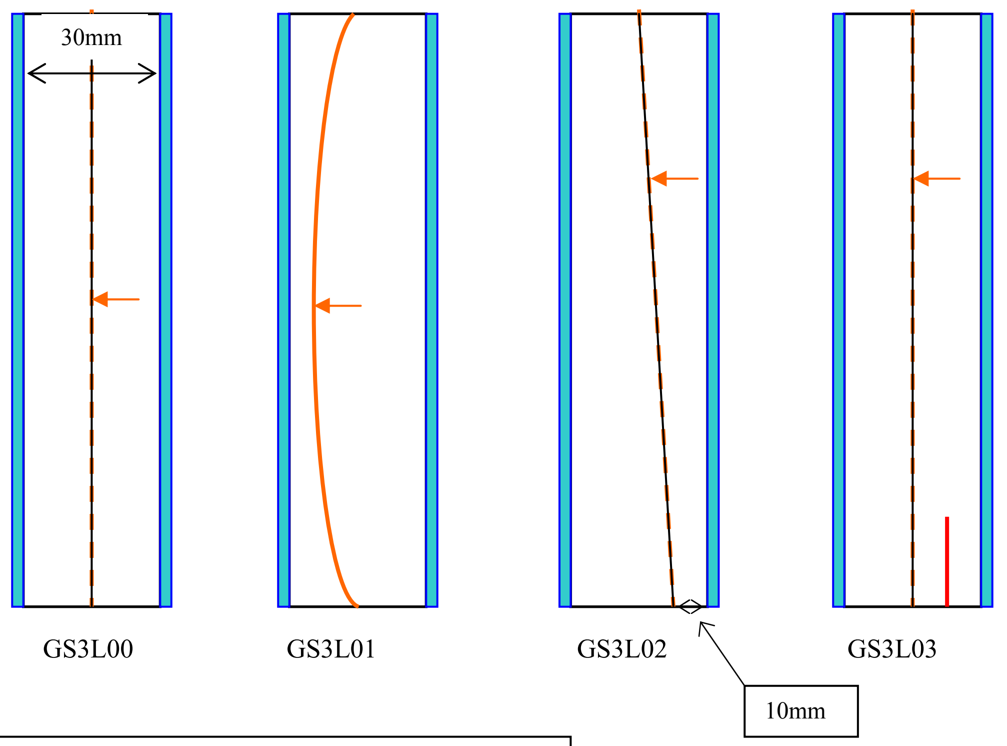
Table 1.
The comparison of the thermal transmittance (U-factor) and minimal inside surface temperature of double IG units with and without inserts ($\Delta T = T_h - T_c = 38.9\,^oC$, H = 1.2 m, Tvis = 0.745).

| Thermal properties | Distance between glasses 16.5 mm, ε = 0.16 | |
|---|---|---|
| | Basis IG unit | IG unit with inserts |
| Ro, $m^{2o}C/W$ | 0.575 | 0.579 |
| U, $W/(m^{2o}C)$ | 1.738 | 1.728 |
| $T_{min}$, $^oC$ | 3.6 | 7.5 |
| SET* | 0.413 | 0.412 |

* Note: total Solar Energy Transmittance (SET) was calculated according to procedure and boundary conditions of ISO 15099 and using grand-band radiation model (Fluent's Discrete Ordinates radiation model [1])

## 2 Three layer IG unit with low-e film

As a basis IG unit for comparison thermal properties we used air filled glazing system with two gaps W = 15 mm (H = 1.0 m, glass width 4.7 mm) and with low-e thin film (ε = 0.052) between gaps. Boundary conditions accepted in numerical modeling are analogue ones shown in Figure 1.




**key**

GS3L00 – basis IG unit with film. e = 0.052

GS3L01 – IG unit with 3-Dim curved film e = 0.052

GS3L02 – IG unit with tilted film e = 0.052

GS3L03 – basis IG unit with plastic translucent insert

→ side with low –e coating

Figure 5. Schemes of possible variants of IG unit with low-e plastic film.

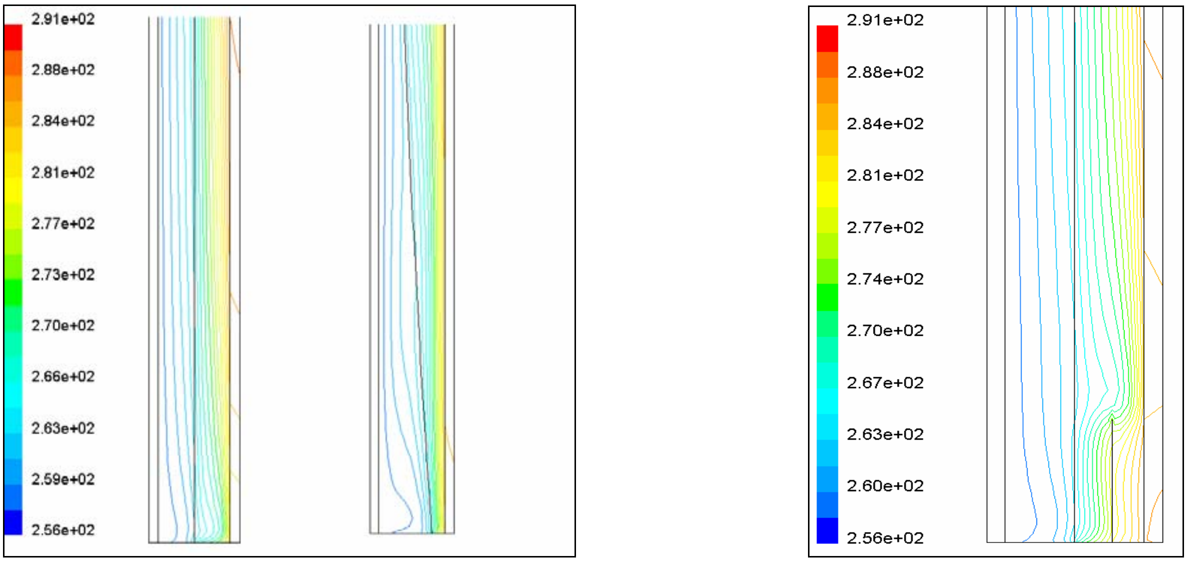



Figure 6. Temperature distribution in the bottom part of basis IG unit, IG unit with curved film and in IG unit with insert.

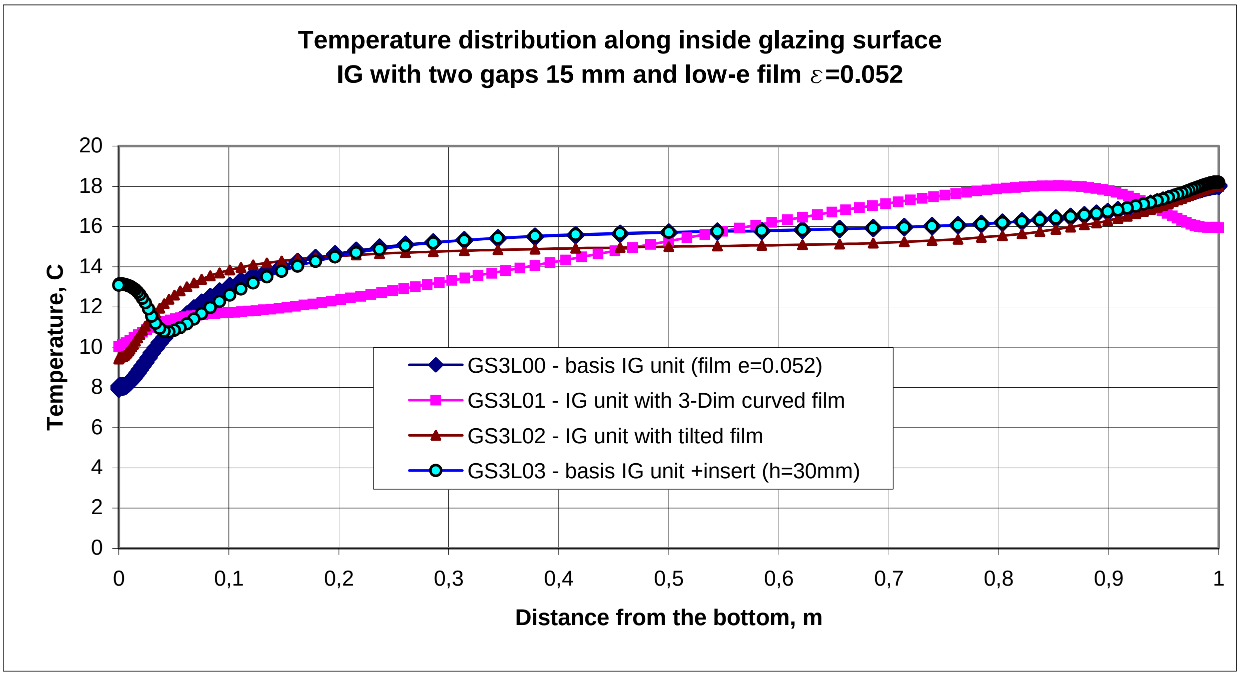



Figure 7. Comparison temperature distributions along inside glazing surface of IG units with film.

Results of numerical modeling are summarized in the Table 2.

Table 2.
The comparison of the thermal transmittance and minimal inside surface temperature of triple IG units with low-e film ($\Delta T = T_h - T_c = 38.9\,^oC$, H = 1.0 m, Tvis = 0.675).

| Thermal properties | IG units with plastic low-e coating film, ε = 0.052 (Figure 5) | | | |
|---|---|---|---|---|
| | GS3L00 | GS3L01 | GS3L02 | GS3L03 |
| Ro, $m^{2o}C/W$ | 0.860 | 0.819 | 0.817 | 0.864 |
| U, $W/(m^{2o}C)$ | 1.163 | 1.221 | 1.223 | 1.157 |
| $T_{min}$, $^oC$ | 8.0 | 10.0 | 9.5 | 10.6 |
| SET | | | | |

3 Four layer IG units with two films

As a basis IG unit for comparison thermal properties we used air filled glazing system with three gaps W = 10 mm (H = 1.0 m, glass width 4.7 mm) and with low-e thin plastic film (ε = 0.052) between gaps.
Boundary conditions accepted in numerical modeling are analogue ones shown in Figure 1.

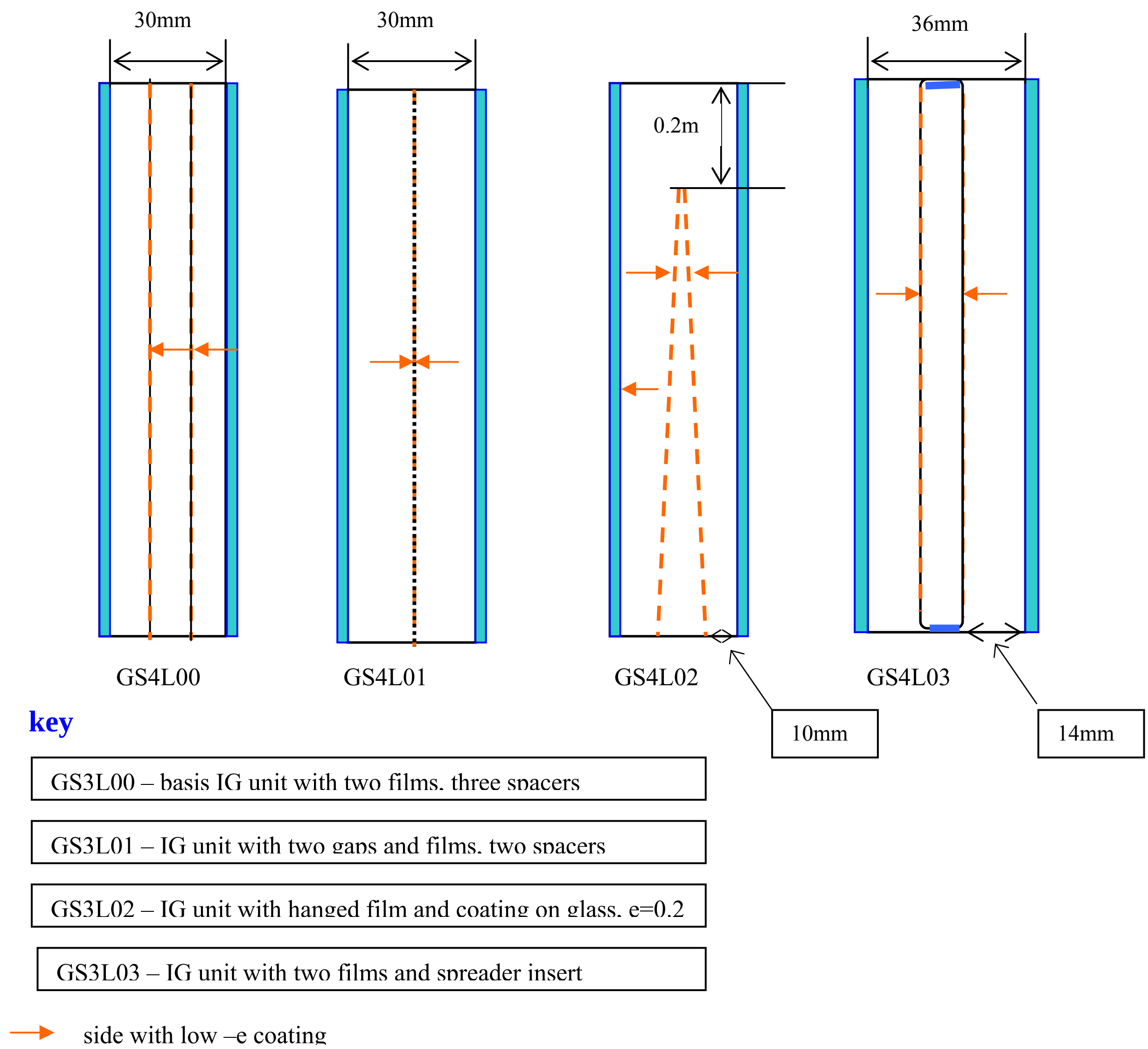



Figure 6. Schemes of possible variants of IG unit with two low-e plastic films.

Results of numerical modeling are summarized in the Table 3.

Table 3.
The comparison of the thermal transmittance and minimal inside surface temperature of IG units with two low-e films ($\Delta T = T_h - T_c = 38.9\,^oC$, H = 1.0 m).

| Thermal properties | IG units with plastic low-e coating films, ε = 0.052 (Figure 6) | | | |
|---|---|---|---|---|
| | GS4L00 | GS4L01 | GS4L02 | GS4L03 |
| Ro, $m^{2o}C/W$ | 1.10 | 1.115 | 0.864 | 1.269 |
| U, $W/(m^{2o}C)$ | 0.910 | 0.897 | 1.157 | 0.788 |
| $T_{min}$, $^oC$ | 13.6 | 9.5 | 13.5 | 11.8 |
| Tvis | 0.566 | 0.566 | 0.6? | 0.566 |
| SET | | | | |

4 Blind with translucent slats inside IG unit

Here is considering scheme of IG unit with placed inside blind with or without low-e films on translucent slats that can have manual or/and remote control using solar or usual batteries. It is supposed that this IG unit can be used as shading device providing also low-level thermal transmittance as a triple IG unit.

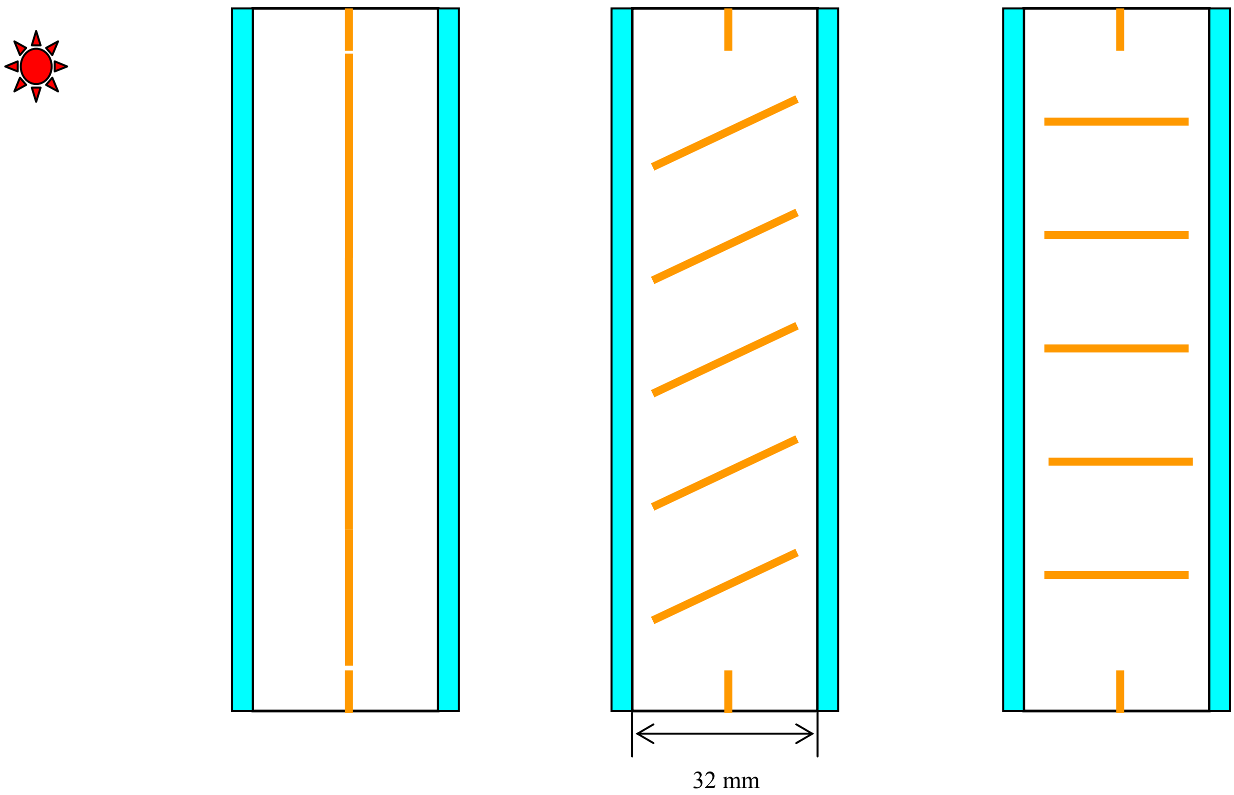



Figure 7. Scheme of working slat positions of the blind inside IG unit.